DESCRIPTION

PHOTOELECTRIC ENCODER

TECHNICAL FIELD

The present invention relates to a photoelectric encoder, and more particularly to an improvement of a photoelectric encoder that has a telecentric optical system in which a lens and an aperture are interposed between a main scale and photoreceptors.

BACKGROUND ART

As described in Japanese Patent Laid-Open Publication No. 2004-264295, a photoelectric encoder has been devised in which, as shown in Fig. 1, a lens optical system (a telecentric optical system) 40 consisting of a lens 42 and an aperture 44 (a telecentric optical aperture) is interposed between a main scale 20 and a photoreception unit 30 made of, e.g., a photoreceptor array 34. As shown in Fig. 2, the distances a and b from the lens 42 to a scale 21 of the main scale 20 and to photoreceptors 35 on the photoreceptor array 34 can thus be adjusted for magnification setting. In Fig. 1, 10 denotes a light source, and f denotes the focal length of the lens 42.

In the photoelectric encoder using this telecentric optical system 40, an image on the main scale 20 is projected onto the photoreceptor array 34 via the lens optical system (42, 44). Here, since the aperture 44 is located in the focal position of the lens 42, the image formed on the photoreceptor

array 34 can be prevented from varying in magnification even if the distance (gap) between the main scale 20 and the lens 42 changes as long as the physical relationship among the lens 42, the aperture 44, and the photoreceptor array 34 is unchanged.

Nevertheless, even with the photoelectric encoder using such a telecentric optical system 40, misalignment of the photoreceptors 35 in the gap direction can change the relationship between the distance a from the lens 42 to the main scale 20 and the distance b from the lens 42 to the photoreceptors 35 as shown in Fig. 3. This changes the magnification of the image formed on the photoreception plane 31 significantly with a sharp drop in signal intensity as shown in Fig. 4.

Besides, the signal detection efficiency in the peripheral area also drops due to lens distortion and coma aberration.

Moreover, when miniaturization is intended, the optical system requires a lens that has a shorter focal length (a smaller diameter, in the case of a general-purpose lens). To maintain the aberrations smaller, however, it is necessary (1) to use an aspherical lens or (2) to use a plurality of lenses in combination (with adjustment). There have thus been such problems as a rise in cost and additional man-hours for adjustment.

DISCLOSURE OF THE INVENTION

The present invention has been achieved in view of the foregoing conventional problems, and it is thus an object thereof to improve the signal detection efficiency, increase assembly tolerance, and reduce the man-hours for adjustment.

The foregoing object of the present invention has been achieved by the provision of a transmission type photoelectric encoder having a telecentric optical system in which a first lens and an aperture located at a focal position of the first lens are interposed between a main scale and a photoreceptor, and wherein at least a second lens is interposed between the aperture and the photoreceptor with a focus of the second lens on the aperture, thereby constituting a bilateral telecentric optical system.

Moreover, the second lens is made identical to the first lens and is situated reversely. The second lens can thus inversely correct an aberration occurring from the first lens so that the aberration is cancelled out almost completely.

The foregoing object of the present invention has also been achieved by the provision of a photoelectric encoder having a telecentric optical system in which a first lens and an aperture located at a focal position of the first lens are interposed between a main scale and a photoreceptor, and wherein one or more second bilateral telecentric optical systems including a second aperture and third and fourth

lenses arranged on both sides thereof is/are further interposed between the second lens and the photoreceptor.

The foregoing object of the present invention has also been achieved by the provision of a photoelectric encoder having a telecentric optical system in which two lenses and an aperture located at a focal position of the two lenses are interposed between a main scale and a photoreceptor, and wherein the two lenses are comprising identical lenses having symmetrical front and back shape with regard to central plane perpendicular to optical axis.

Moreover, ~~at least either one of the first lens and the second~~ each of two lenses is made of: a spherical ball lens, which has high distortion but is inexpensive; a GRIN lens of gradient refractive index type (also called SELFOC lens), which refracts light beams in a parabolic pattern inside its lens medium; or a drum lens. This allows compact configuration at low price.

~~Moreover, one or more second bilateral telecentric optical systems including a second aperture and third and fourth lenses arranged on both sides thereof is/are further interposed between the second lens and the photoreceptor.~~

Moreover, the aperture is formed as a slit oblong in a direction perpendicular to an axis of measurement, so that the amount of light to reach the photoreceptor is increased for the sake of power saving and improved reliability of the light

source.

According to the present invention, the second lens can inversely correct the aberration occurring from the first lens. This makes it possible to reduce the aberration and improve the signal detection efficiency.

Moreover, even if the gap between the second lens and the photoreceptors varies, the optical magnification can be maintained constant. This can increase the assembly tolerance in the gap direction and reduce the man-hours for adjustment.

BRIEF EXPLANATION OF THE DRAWINGS

Fig. 1 is a perspective view showing the configuration of essential parts of a photoelectric encoder having a telecentric optical system.

Fig. 2 is a plan view of the same.

Fig. 3 is a ray diagram for explaining variations in magnitude ascribable to misalignment of the photoreceptors of the same in the gap direction.

Fig. 4 is a chart showing an example of variation of the signal intensity of the same.

Fig. 5 is a perspective view showing the configuration of essential parts of a first embodiment of the present invention.

Fig. 6 is a ray diagram of the same.

Fig. 7 is a ray diagram showing the configuration of essential parts of a second embodiment of the present invention.

Fig. 8 is a ray diagram showing the configuration of essential parts of a third embodiment of the present invention.

Fig. 9 is a ray diagram showing the configuration of essential parts of a fourth embodiment of the present invention.

Fig. 10 is a ray diagram showing the configuration of essential parts of a fifth embodiment of the present invention.

Fig. 11 is a ray diagram showing the configuration of essential parts of a sixth embodiment of the present invention.

Fig. 12 is a ray diagram showing the configuration of essential parts of a seventh embodiment of the present invention.

Fig. 13 is a perspective view showing the configuration of essential parts of an eighth embodiment of the present invention.

Fig. 14 is a ray diagram showing the configuration of essential parts of a ninth embodiment of the present invention.

Fig. 15 is a diagram showing the effect of the same.

Fig. 16 is a ray diagram showing the configuration of essential parts of a tenth embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

A first embodiment of the present invention is a photoelectric encoder having a telecentric optical system 40

like shown in Fig. 1. As shown in Fig. 5, a lens 52 identical to the first lens 42 is interposed on the other side of the aperture 44 in a reverse orientation with its focus on the aperture 44, thereby constituting a bilateral telecentric optical system 50. In the diagram, f represents the focal lengths of the lenses 42 and 52.

In the present embodiment, the first lens 42 and the second lens 52 are identical. The second lens 52 can thus inversely correct aberrations occurring from the first lens 42 almost completely. It is therefore possible to cancel out the aberrations almost completely with a significant improvement in the signal detection efficiency.

Moreover, since the second lens 52 is interposed so that its focus falls on the aperture 44, the outgoing light from the second lens 52 becomes parallel light as shown in Fig. 6, and the optical magnification is maintained constant (1x) even when the gap between the second lens 52 and the photoreception plane 31 varies. This makes it possible to increase the assembly tolerance in the gap direction and reduce the man-hours for adjustment.

It should be appreciated that the first and second lenses 42 and 52 need not necessarily be plano-convex lenses which are used outward as shown in Fig. 6, but plano-concave lenses may be used inward as in a second embodiment shown in Fig. 7. Otherwise, biconvex lenses may be used as in a third

embodiment shown in Fig. 8. Otherwise, ball lenses may be used for miniaturization and cost reduction as in a fourth embodiment shown in Fig. 9. Otherwise, GRIN lenses may be used for miniaturization and cost reduction as in a fifth embodiment shown in Fig. 10. Otherwise, drum lenses may be used for miniaturization and cost reduction as in a sixth embodiment shown in Fig. 11.

Moreover, as in a seventh embodiment shown in Fig. 12, the second lens 54 may be made different from the first lens 42 so as to change the optical magnification between the IN side and the OUT side to other than 1x. In the diagram, F represents the focal length of the second lens 54.

In this case, it might be impossible to eliminate aberrations completely, whereas the assembly tolerance in the gap direction increases.

Moreover, the aperture may have a non-circular shape. As in an eighth embodiment shown in Fig. 13, a slit 46 oblong in the direction perpendicular to the axis of measurement may be formed so that the amount of light to reach the photoreception plane 31 is increased for the sake of power saving and improved reliability of the light source 10. Alternatively, the aperture may have an elliptic or oval shape.

Furthermore, as in a ninth embodiment shown in Fig. 14, the number of apertures of the bilateral telecentric system 50 may be increased along the axis of measurement. This widens

the on-scale field of view (FOB) by image superposition, provides robustness against stains and wobbles by the averaging effect, and increases the amount of light to reach the photoreception plane 31, thereby allowing power saving and improved reliability of the light source 10.

Moreover, the number of lenses to be added is not limited to one. As in a tenth embodiment shown in Fig. 16, another bilateral telecentric system 60 consisting of lenses 62 and 64 and an aperture 66 may be added. Here, the lenses 62 and 64 may be the same as or different from the lenses 42 and 52. The number of bilateral telecentric systems to be added is not limited to one, either. Two or more systems may be added.

INDUSTRIAL APPLICABILITY

The present invention is applicable to either of an encoder in which the index grating and the photoreceptors are formed separately and an encoder having a photoreceptor array having the two components formed integrally. Moreover, it is applicable not only to encoders of transmission type, but to encoders of reflection type as well.

CLAIMS

1. (Amended) A transmission type photoelectric encoder having a telecentric optical system in which a first lens and an aperture located at a focal position of the first lens are interposed between a main scale and a photoreceptor, and

wherein at least a second lens is interposed between the aperture and the photoreceptor with a focus of the second lens on the aperture, thereby constituting a bilateral telecentric optical system.

2. The photoelectric encoder according to claim 1, wherein the second lens is made identical to the first lens and is situated reversely.

3. (Deleted) ~~The photoelectric encoder according to claim 1 or 2, wherein at least either one of the first lens and the second lens is made of a ball lens.~~

4. (Deleted) ~~The photoelectric encoder according to claim 1 or 2, wherein at least either one of the first lens and the second lens is made of a GRIN lens.~~

5. (Deleted) ~~The photoelectric encoder according to claim 1 or 2, wherein at least either one of the first lens and the second lens is made of a drum lens.~~

6. (Amended) ~~The~~ A photoelectric encoder ~~according to any of claims 1 to 5,~~ having a telecentric optical system in which a first lens and an aperture located at a focal position of the first lens are interposed between a main scale and a

photoreceptor, and wherein one or more second bilateral telecentric optical systems including a second aperture and third and fourth lenses arranged on both sides thereof is/are further interposed between the second lens and the photoreceptor.

7. (Deleted) ~~The photoelectric encoder according to any of claims 1 to 6, wherein the aperture is formed as a slit oblong in a direction perpendicular to an axis of measurement.~~

8 (Added). A photoelectric encoder having a telecentric optical system in which two lenses and an aperture located at a focal position of the two lenses are interposed between a main scale and a photoreceptor, and wherein the two lenses are comprising identical lenses having symmetrical front and back shape with regard to central plane perpendicular to optical axis.

9 (Added). The photoelectric encoder according to claim 8, wherein each of the two lenses is made of a ball lens.

10 (Added). The photoelectric encoder according to claim 8, wherein each of the two lenses is made of a GRIN lens.

11 (Added). The photoelectric encoder according to claim 8, wherein each of the two lenses is made of a drum lens.

12 (Added). The photoelectric encoder according to any of claims 1, 2, 6, and 8 to 11, wherein the aperture is formed as a slit oblong in a direction perpendicular to an axis of measurement.

ABSTRACT

A photoelectric encoder has a telecentric optical system in which a first lens and an aperture located at a focal position of the first lens are interposed between a main scale and a photoreceptor. At least a second lens is interposed between the aperture and the photoreceptor with a focus of the second lens on the aperture, thereby constituting a bilateral telecentric optical system. This makes it possible to improve the signal detection efficiency and increase the assembly tolerance.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/004924

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] G01D5/36, G02B13/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] G01D5/36, G02B13/22

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2005
Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 26179/1983(Laid-open No. 134006/1984) (Yokokawa Hokushin Denki Kabushiki Kaisha), 07 September, 1984 (07.09.84), Full text; all drawings (Family: none)	1,3-5,7 2
Y	JP 2003-21787 A (Nikon Corp.), 24 January, 2003 (24.01.03), Par. No. [0030]; Fig. 1 (Family: none)	2

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 April, 2005 (11.04.05)	26 April, 2005 (26.04.05)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/004924

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-307440 A (Omron Corp.), 31 October, 2003 (31.10.03), Full text; all drawings & DE 10304854 A & US 2003/209658 A	1-7
A	JP 2002-231604 A (Nikon Corp.), 16 August, 2002 (16.08.02), Full text; all drawings (Family: none)	1-7
A	JP 62-200223 A (Canon Inc.), 03 September, 1987 (03.09.87), Full text; all drawings & GB 2186362 A & DE 3700777 A & US 5059791 A	1-7

国際調査報告

国際出願番号 PCT／JP2005／004924

A. 発明の属する分野の分類（国際特許分類（IPC））

Int.Cl.[7] G01D5/36, G02B13/22

B. 調査を行った分野

調査を行った最小限資料（国際特許分類（IPC））

Int.Cl.[7] G01D5/36, G02B13/22

最小限資料以外の資料で調査を行った分野に含まれるもの

日本国実用新案公報	1922－1996年
日本国公開実用新案公報	1971－2005年
日本国実用新案登録公報	1996－2005年
日本国登録実用新案公報	1994－2005年

国際調査で使用した電子データベース（データベースの名称、調査に使用した用語）

C. 関連すると認められる文献

引用文献のカテゴリー＊	引用文献名 及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
X Y	日本国実用新案登録出願58－26179号（日本国実用新案登録出願公開59－134006号）の願書に添付した明細書及び図面の内容を撮影したマイクロフィルム（横河北辰電機株式会社）1984．09．07、全文、全図（ファミリーなし）	1、3－5、7 2
Y	JP 2003－21787 A（株式会社ニコン）2003．01．24、段落番号【0030】、第1図（ファミリーなし）	2

☑ C欄の続きにも文献が列挙されている。

☐ パテントファミリーに関する別紙を参照。

＊ 引用文献のカテゴリー

「A」特に関連のある文献ではなく、一般的技術水準を示すもの

「E」国際出願日前の出願または特許であるが、国際出願日以後に公表されたもの

「L」優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献（理由を付す）

「O」口頭による開示、使用、展示等に言及する文献

「P」国際出願日前で、かつ優先権の主張の基礎となる出願の日の後に公表された文献

「T」国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの

「X」特に関連のある文献であって、当該文献のみで発明の新規性又は進歩性がないと考えられるもの

「Y」特に関連のある文献であって、当該文献と他の1以上の文献との、当業者にとって自明である組合せによって進歩性がないと考えられるもの

「&」同一パテントファミリー文献

国際調査を完了した日 11．04．2005	国際調査報告の発送日 26.4.2005
国際調査機関の名称及びあて先 日本国特許庁（ISA／JP） 郵便番号100－8915 東京都千代田区霞が関三丁目4番3号	特許庁審査官（権限のある職員） 井上 昌宏 電話番号 03－3581－1101 内線 3216
	2F 9504

様式PCT／ISA／210（第2ページ）（2004年1月）

C（続き）．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
A	JP　2003－307440　A（オムロン株式会社）2003．10．31、全文、全図&DE　10304854　A&US　2003／209658　A	1－7
A	JP　2002－231604　A（株式会社ニコン）2002．08．16、全文、全図（ファミリーなし）	1－7
A	JP　62－200223　A（キヤノン株式会社）1987．09．03、全文、全図&GB　2186362 A&DE　3700777　A&US　5059791　A	1－7